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(54) Apparatus and Process for the Refinement of Molten Metal

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Abstract of the Disclosure:

A reaction vessel for the refinement of molten metal comprises an inlet chamber which communicates with a holding furnace and is equipped with means for heating the molten metal flowing into the inlet chamber, at least one reaction chamber which communicates with the inlet chamber and has an opening in its roof through which a rotary injection device may be inserted, and a settling chamber which communicates with the reaction chamber and contains a taphole on an exterior wall of the vessel. The reaction vessel is preferably a bay within the holding furnace which is isolated from the hearth of the holding furnace by means of a high thermal conductive wall extending alongside the wall of the furnace, such high thermal conductive wall having a sub-surface metal eye opening communicating with the inlet chamber of the reaction vessel.

APPARATUS AND PROCESS FOR THE REFINEMENT OF

MOLTEN METAL

This invention relates to refinement of molten metal, particularly liquid aluminum, for the removal of

5   solute hydrogen, non-metallic inclusions, and alkali/alkaline earth elements.

Hydrogen in molten aluminum causes micro or macro porosity or shrinkage cavity in the cast product depending on the solidification rate. In addition, even

10   the pore free cast metal can yield internal porosity and/or blisters on the product surface, following heat treatment process, due to diffusion of monatomic hydrogen in the solid matrix to form molecular hydrogen which dilates and causes these defects.

15   Non-metallic inclusions in the liquid originate from a number of sources (eg. solute carbon from electrolytic reduction, oxygen and carbon from gas burners in the furnace, oxygen and hydrogen from the humidity in air, etc.). Presence of inclusions contributes to faster

20   die wear during extrusion, tool wear during machining, and tears during rolling.

Alkali   and   alkaline   earth   metals   in

concentratio● above - 5 ppm (total) ●ribute to brittleness of the solid metal and hence result in excessive edge trimming in sheet and foil products and tearing during extrusion of the billets.

5   Furnace fluxing in the casthouses has been commonly relied upon to refine molten aluminum via lancing. Pure chlorine or varying concentrations of chlorine - inert gas mixtures are routinely injected into the aluminum bath via graphite or enamelled iron pipes for

10   removing unwanted impurities (hydrogen, non-metallic inclusions and alkali/alkaline earth metals). However, refinement by lancing produce undesirable consequences of drossing and emissions.

           Dross is an oxidation product caused by exposure

15   of the metal to the atmosphere, and it is a loss not only through oxidation of metal but also through additional handling and disposal cost. Therefore, the formation of dross should be minimized by reducing the degree of turbulence of liquid metal.

20   Chlorine injection into an aluminum melt causes rapid formation of $AlCl_3$ which is a gaseous compound at aluminum making temperatures. Upon contacting moisture in the air, aluminum chloride hydrolyzes to form Al_2O_3 fume and HCl, both of which are pollutants. In magnesium

25   containing melts chlorine reacts preferentially to form $MgCl_2$, which can in turn hydrolyze to give MgO and HCl.

Finally, part of the chlorine is emitted in the form of free chlorine. Free chlorine hydrolyzes to form HCl which is responsible for corrosion. Furnace fluxing via lancing results in the formation of large gas bubbles containing chlorine which are confined to the bubble plume. Due to the limited residence times of these bubbles in the melt, large proportions of the injected chlorine escape the metal partially reacted and/or unreacted.

To circumvent the shortcomings of furnace fluxing more and more casthouses are employing in-line units based on rotary nozzle gas dispersion technique, as in the Union Carbide SNIF system (U.S. Patents: 3,743,263; 3,870,511; and 4,047,938 and in Canadian Patents: 981,912 and 1,095,732). This technology creates small inert gas bubbles which are dispersed throughout the molten metal bath in a degassing chamber which is external to the furnace. The very large surface/volume ratios obtained with this technique, excellent dispersion of micro bubbles within the melt, and large energy densities imparted to the melt are responsible for increased reaction rates and hence rapid reduction of solute hydrogen and alkali/alkaline earth removal, relatively low dross formation and emissions, and good non-metallic inclusion removal by flotation.

There are, however, shortcomings of such systems. Liquid chlorides (alkali/alkaline earth halides)

that are formed during treatment are finely dispersed throughout the liquid metal. This phenomenon is especially troublesome in high magnesium alloys ($MgCl_2$

5   formation). Due to the limited treatment time, part of these chlorides cannot float out of the melt. These chlorides are carried through to the casting table where they cause number of surface and sub-surface defects in the cast product known as oxide patches.

In addition, relatively large operating costs

10   are associated with the use of in-line units which are caused by maintenance of an external unit (i.e. refractory tub and immersion heater replacement costs in addition to fluxing gas mixture and graphite assembly cost).

Requirement for large floor spaces on already

15   overcrowded casthouses is another drawback. It is often very difficult to fit these units onto floor spaces of casthouses that were designed and built prior to the development of in-line units, but are still operational. In many cases difficult and costly renovations to the

20.   casthouse are needed.

It is the object of the present invention to provide an apparatus and a process for the refinement of molten metal, particularly aluminum, which overcomes the shortcomings of furnace fluxing.

25   It is also an object of the present invention to

provide an apparatus and a process which allows refinement of molten metal, particularly aluminum, in a holding furnace bay thereby eliminating the need of separate in line units.

5   The apparatus in accordance with the present invention is a reaction vessel comprising an inlet chamber which communicates with a holding furnace and is equipped with means for heating the metal flowing into the inlet chamber, at least one reaction chamber which communicates

10   with the inlet chamber and has an opening in the roof thereof through which a rotary injection device may be inserted, and a settling chamber which communicates with the reaction chamber and contains a taphole on the exterior wall of the vessel.

15   The reaction vessel is preferably a bay within a holding furnace. The holding bay is preferably isolated from the hearth of the holding furnace by means of a wall made of high thermal conductive material, such as a silicon carbide, extending along one wall of the furnace,

20   the high thermal conductive wall having a sub-surface metal eye opening communicating with the inlet chamber.

           The reaction chamber preferably consists of a first stage reaction chamber and a second stage reaction chamber, the chambers being interconnected through an

25   underflow opening and each chamber having a roof opening for the insertion of a rotary injection device.

The inlet chamber is separated from the first stage reaction chamber, the first stage reaction chamber from the second stage reaction chamber, and the second stage reaction chamber from the settling chamber by high

5   thermal conductive walls having the above mentioned underflow openings at the bottom.

Vertical baffles are preferably incorporated on either sides of the reaction chambers and located directly in front of each rotary injection device to minimize

10   splashing and vortexing of the liquid metal and thus excessive dross formation.

Each rotary injection device comprises a rotary shaft preferably made of graphite and having a central passage therein for feeding a fluxing gas mixture

15   consisting of inert gas containing less than 5% chlorine, and an impeller with equally spaced blades, preferably nine, and radial orifices located between the blades and connected to the central passage of the shaft. The radial orifices are preferably connected to a central windbox

20   within the impeller which is itself connected to the central passage of the shaft. The shaft is driven by a motor drive assembly located above the roof of the bay.

The process for removing solute hydrogen, alkali/alkaline earth metals, and non-metallic inclusions,

25   while minimizing dross formation, diminishing oxide pach occurence, during metal flow from a holding furnace to a

casting table comprises the steps of (a) shutting off the gas burner in the reaction vessel and introducing a rotary injection device into the reaction chamber or chambers of the reaction vessel, (b) creating an inert atmosphere within the reaction vessel, (c) introducing argon-chlorine fluxing gas mixture into the reaction chamber or chambers through the rotary injection devices for a predetermined injection period, (d) tapping out the refined molten metal from the taphole in the settling chamber continuously, while feeding untreated molten metal into the inlet chamber and continuing to inject fluxing gas mixture into the molten metal in the reaction chamber or chambers, (e) collecting most of the non-metallic inclusions and halides in a dross layer above the liquid metal in the reaction chamber or chambers, (f) collecting the remaining suspended halide droplets and the runaway dewetted non-metallic inclusions in the settling chamber of the reaction vessel, (g) allowing the molten metal height to drop to a minimum level determined to be equal to the height of the taphole in the settling chamber, (h) stopping the metal flow through the taphole and transferring a new batch of molten metal into the reaction vessel thereby raising the metal level, and (i) removing the dross from the surface layer of the liquid metal by skimming.

The inert atmosphere within the reaction vessel

is maintained higher than atmospheric pressure thereby creating a positive pressure and eliminating the possibility of hydrogen pick-up from the atmosphere.

The invention will now be disclosed, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a top view of a holding furnace bay in accordance with the present invention;

Figure 2 is a longitudinal cross section of the furnace bay shown in Figure 1;

Figure 3 is a transverse section of the furnace bay shown in Figure 1 which displays the elevation difference between the furnace hearth and the furnace bay;

Figure 4 is a longitudinal cross section of the furnace bay during metal processing and showing rotary injection devices in position in the reaction chambers;

Figure 5 is a top view of an external reaction vessel with inlet, first and second reaction and settling chambers;

Figure 6 is a perspective view of a rotary injection device used in the holding furnace bay or reaction vessel in accordance with the invention; and

Figures 7a and 7b are detailed views of the impeller of the rotary injection device of Figure 6.

Referring to Figures 1 to 4, there is shown a holding furnace bay 10 which is an isolated section of a

holding furnace 12. In this arrangement, the furnace bay is isolated from the hearth 14 of the holding furnace by means of a high thermal conductive wall 16 which extends from furnace floor to ceiling. The only communication

5 between the furnace hearth and the furnace bay is through an opening 18 below the metal level called a metal eye. The furnace bay is divided into four distinct sections, by means of three high thermal conductive partition walls 19, 20 and 21. These sections are: an inlet chamber 22, first

10 stage reaction chamber 23, second stage reaction chamber 24, and a settling chamber 25. Access to each of the furnace bay sections from outside can be achieved through a multiplicity of openings, such as skimming doors 26, 27, 28 and 29. Molten metal removal can be achieved through

15 tap holes. In Figure 1 two possible locations for metal tap-out and furnace draining are illustrated: taphole 30 on the short outside wall of the settling chamber 25, and taphole 30a on the long outside wall of the same chamber. Communication between the four bay chambers is achieved by

20 means of underflow openings 31, 32 and 33. In order to maximize the metal refinement efficiency the size of these underflow openings should be about 4.5% of the wetted area of the partition walls. The height of each underflow opening should not be larger than twice the thickness of

25 the impeller blade of the rotary injection devices (to be disclosed later). As shown in Figure 4, two rotary
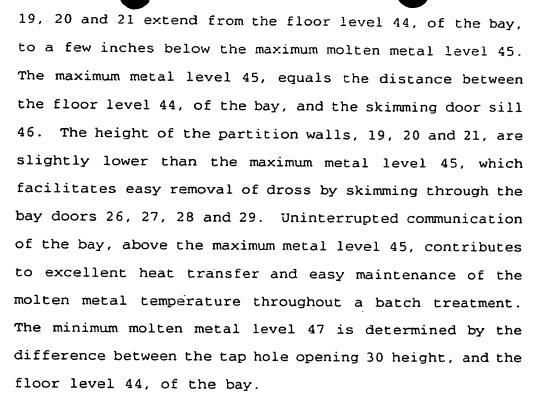
injection devices are employed one in each of the first and second stage reaction chambers 23 and 24. Each reaction chamber is preferably squared shape, although a rectangular geometry is also acceptable. In the case of
5   the latter shape, the longer side 34, should not be greater than 1.5 times the shorter side 35. To minimize splashing and vortexing of the liquid metal and thus excessive dross formation, two baffles are incorporated in each of the reaction chambers 23 and 24, opposite to each
10   other 36, 37 and 38, 39 respectively. The ratio of the baffle thickness 40 to equivalent cell diameter 35 is between 0.10 and 0.15. In the case of a rectangular shaped cell, the baffles are located on the longer side, as shown in Figure 1. In a square shaped cell these
15   baffles may not be needed. In this arrangement, molten metal enters the inlet chamber 22 of the furnace bay from the furnace hearth 14, via metal-eye 18, travels through the underflow openings 31, 32 and 33, and exits the bay through one of the tap holes 30 or 30a.
20   Heating of the molten metal in the bay can be achieved by different methods. In this case, it is being effected by means of a roof mounted gas burner 41. Off gases are exhausted through a roof opening 42, above the settling chamber 25. A damper 43 is used in the roof
25   opening 42 to control the bay atmosphere. The location of the exhaust opening is not critical. The partition walls

19, 20 and 21 extend from the floor level 44, of the bay, to a few inches below the maximum molten metal level 45. The maximum metal level 45, equals the distance between the floor level 44, of the bay, and the skimming door sill 46. The height of the partition walls, 19, 20 and 21, are slightly lower than the maximum metal level 45, which facilitates easy removal of dross by skimming through the bay doors 26, 27, 28 and 29. Uninterrupted communication of the bay, above the maximum metal level 45, contributes to excellent heat transfer and easy maintenance of the molten metal temperature throughout a batch treatment. The minimum molten metal level 47 is determined by the difference between the tap hole opening 30 height, and the floor level 44, of the bay.

In order to reduce excessive dross formation the minimum metal level 47 should preferably equal 1.4 times the diameter of the impeller of the rotary injection devices (to be disclosed later). This can be achieved in number of ways. In the present invention this is achieved by lowering the bay floor 44 with respect to the furnace hearth 14, as shown in Figure 3. Another possible option is to raise the height of the tap holes 30 or 30a, and all furnace and bay windows heights 26, 27, 28 and 29 slightly. In most casthouses the height of the holding furnace heel, which is the molten metal left at the end of a single drop, is more than the minimum metal level

required by this process, making these modifications to the furnace unnecessary.

Figure 5 shows an alternative design of a reaction vessel of similar geometry placed external to the holding furnace. All the components of this external reaction vessel are essentially the same as the furnace bay except for the inlet 48, and the outlet 49. The inlet 48 can be coupled to the holding furnace through one of the three outside walls of the inlet chamber 22 of the external unit. Similarly, the outlet 49 can be placed through either of the three outside walls of the setting chamber 25 of the external unit and allows metal to go to a casting station, preferably through a filter. While this alternate design will address the problem of chloride inclusion entrainment, it will, however, have the following shortcomings of the in-line units: relating high operating cost (i.e. additional refractory and steel frame for the external unit, immersion heater(s) and additional heat requirements) and large floor space.

Figure 4 illustrates two rotary injection devices which are inserted into the first and second reaction chambers through roof openings 50 and 51. Figure 6 is an enlarged view of the rotary injection device which consists of a hollow shaft 52 which is coupled to an impeller 53. The shaft has a central passage 54 which is connected to a rotary joint 55 for delivery of a fluxing

gas mixture to the reaction chambers. The rotary injection device is driven by a drive mechanism 56 which consists of a hollow steel shaft 57 with heat transfer fins 58, a motor 59 and pulley and belt mechanism 60.

5   The impeller cross sectional and top views are shown in Figures 7a and 7b, respectively. There are nine orifices 61, for gas injection which are located between the blades 62. A windbox 63 which is an empty volume of the impeller is provided in the shaft-impeller assembly to

10   provide a housing for any liquid metal droplet which may enter the impeller. It is located between the bottom end of the shaft 52 and the impeller orifices 61. Any liquid metal droplet which may enter the impeller through the orifices 61, solidifies within the windbox 63, due to

15   lower temperature within the windbox caused by the relatively cool fluxing gas mixture. To minimize the chance of molten metal entering the impeller windbox 63, and plugging the orifices 61, and passage 54 in the shaft 52, the orifice gas velocity is maintained between 5 and

20   70 m/s. The ratio of the impeller blade thickness 65 to its diameter 66 should be at least 0.3.

The furnace rotary gas injection devices are capable of delivering high energy densities required to agglomerate the small non-metallic inclusions by rotating

25   its impellers and causing high degree of agitation within the body of metal while eliminating vortexing due to the

presence of the baffles 36, 37, 38 and 39 in the first and second stage reaction chambers, and hence reducing the dross formation. Due to restriction of communication between each of the bay chambers through small underflow openings, the body of molten metal which is treated at any one time receives large energy densities for effective agglomeration of non-metallic inclusions.

The two rotary injection devices which deliver large volumes of fluxing gas mixtures into the two reaction chambers shear the gas into large number of micro bubbles and disperse them throughout the reaction chamber, providing large surface to volume ratios that impact, intercept and float out the non-metallic inclusions and their agglomerates to the dross layer above the melt.

The addition of a small percentage of chlorine in 0.01-5.0 v/o ratios in the inert gas mixture ensures the reduction of the surface tension between the non-metallic inclusions and the liquid metal, resulting in an increase in inclusion removal efficiency as compared to inert gas alone. In excess of 95% of this chlorine reacts in the metal with alkali/alkaline earth metals and form halides. Therefore the pollutant emissions into the atmosphere is virtually eliminated.

Up to 5% chlorine addition into the fluxing gas mixture ensures, besides the enhancement of non-metallic inclusion removal, the fast reduction of alkali and

alkaline earth metals by forming corresponding halides: $CaCl_2$, NaCl, LiCl, $MgCl_3$, $AlCl_3$. These halides float out of the molten metal at a slower rate than the fluxing gas bubbles due to the former's smaller relative density

5   difference with the liquid metal. Therefore, though the fluxing gas bubbles quickly float out of the molten metal in the reaction chambers, considerable portion of the chloride droplets remain in the melt, as the metal leaves the second stage reaction chamber. The superiority of the

10   present invention compared to so called in-line units in this respect is that these entrained chloride droplets carried over from the reaction chambers float out of the melt in the settling chamber where they end up in the dross layer and are subsequently removed by skimming. The

15   settling chamber is also maintained under inert atmosphere. Failure to float out these chlorides accelerate the oxidation of liquid metal in the transfer troughs and on the liquid metal head atop the casting table. Unwanted entrainment of these hard oxide skim

20   pieces into the cast product is known to result in surface and sub-surface oxide patches which cause a costly operation of scalping or scrapping of the product.

       The minimum solute hydrogen levels attainable by this process is governed by the competing reactions

25   between humidity and metal that results in hydrogen pick-up, and between fluxing gas bubble and metal that results

in hydrogen removal. Since the number of micro bubbles are very large and the solubility of hydrogen is lower in the liquid aluminum, the reduction of hydrogen is limited by its diffusion through liquid aluminum. Therefore a high degree of agitation in the two reaction chambers results in increased diffusion of monatomic hydrogen from the liquid aluminum to the inert fluxing bubbles, and its subsequent removal from the melt by flotation from the molten metal.

The above disclosed apparatus operates as follows:

Refinement of the metal starts once the molten metal level in the holding furnace is raised to its maximum 45, and it is skimmed of its dross through bay doors 26, 27, 28 and 29. At the beginning of the process the bay is sealed off from the external atmosphere by shutting the doors 26, 27, 28 and 29, and the exhaust damper 43 tightly. In addition the gas burner 41, of the bay is turned off. The two rotary injectors are inserted into the metal through roof openings 50 and 51, while small amount of inert gas flows through their central channels, via rotary joint 55, hollow steel shaft 57, shaft 52, and impeller 53 route. This is required to prevent molten metal from flowing into the impellers through the orifices 61. When the injectors are in their operating positions, refractory plugs 67 and 68 (Figure

4), around the shafts 52, seal the bay from external atmosphere completely. The operating position of the impeller equals to a height equivalent to the impeller blade thickness above the bay floor 44.

5   Once the injectors are in place, they are rotated at the chosen operating speed by means of the drive mechanism 56, and the fluxing gas mixture consisting of inert gas + chlorine (<5.0 v/o) is injected with pre-determined volumes into the metal. The fluxing gas

10   mixture exits the impeller orifices 61, and is sheared off by the rapidly rotating blades 62, and transformed into large number of micro bubbles. These bubbles refine the metal and escape the melt through metal-air interface 45, and quickly replace the air inside the bay with relatively

15   inert fluxing gas mixture, and creating a positive pressure.

From the time of its entry into the molten metal through impeller orifices 61, until its escape from the furnace bay, the fluxing gas accomplishes the following

20   tasks: (a) removes hydrogen: the well dispersed inert micro bubbles provide sites for monatomic hydrogen to diffuse into. Solute hydrogen is reduced continuously by these bubbles as they escape the melt through metal-inert atmosphere interface 45, (b) removes alkali and alkali

25   earth metals: chlorine in the fluxing gas mixture reacts with these elements and form corresponding halides. These

halides fl● out of the metal to t● melt-inert atmosphere interface 45, mostly in the first and second reaction chambers 23 and 24, (c) removes non-metallic inclusions: inclusions and their agglomerates are

5 intercepted, impacted, and floated out of the molten metal, to the melt-inert atmosphere interface 45, by these well dispersed micro bubbles, and (d) provides inert atmosphere: when these small bubbles escape the melt and burst the inert gas replaces the air and create a positive

10 pressure inside the bay and preventing any air infiltration.

The partition walls 19, 20 and 21 confine the gas bubbles mostly to the reaction chambers 23 and 24. Therefore most of the dross and halides that are formed as

15 a result of injection process is confined to the surface of these reaction chambers. The amount of dross formed is minimized due to elimination of vortexing and splashing by means of vertical baffles 36, 37, 38 and 39, placed on two opposite sides of the injectors.

20 Before the start of casting, the injection process as described above is initiated and continues for a predetermined period, and the molten metal inside the bay is refined to reduce the hydrogen, alkali and alkaline earth metals, and non-metallic inclusions to acceptable

25 levels.

Following this initial injection period, the

metal is withdrawn from the furnace bay through taphole 30
or 30a in the settling chamber. While the refined metal
leaves the bay through a taphole, untreated metal enters
it through the metal eye 18, passes through the underflow

5   opening 31 of the partition wall 19 of the first stage
reaction chamber, where its hydrogen, alkali and alkaline
earth metals, and non-metallic inclusions levels are
reduced by the first rotary gas injector. Metal exiting
the first stage reaction chamber 23, enters into the

10   second stage reaction chamber 24, through underflow
opening 32 of the partition wall 20. Hydrogen content,
alkali and alkaline earth metals, and the non-metallic
inclusions of the melt are further reduced by the second
rotary injector. Refined metal exits the second stage

15   reaction chamber 24, through the underflow opening 33, of
the partition wall 21, and enters the settling chamber 25.
It is to be understood that a single reaction chamber may
be sufficient depending on the metal refining
requirements, which include hydrogen, alkali and alkaline

20   earth metals and non-metallic inclusions. Similarly, more
than two reaction chambers may be required to achieve
acceptable refining levels. Any remaining gas bubbles,
liquid halides, and dross that are carried over from the
reaction chambers 23 and 24, float out in the settling

25   chamber 25 before metal exits the furnace bay through a
taphole 30 or 30a.

As the refined liquid metal is withdrawn from the holding furnace via a taphole in the settling chamber the metal level in the furnace bay descends from its maximum 45, to minimum 47. When the casting process is complete, the taphole 30 or 30a, is blocked and the flow of metal is interrupted. At this stage a new batch of metal is charged into the holding furnace hearth 14. This, in turn, raises the metal level back to its maximum 45, due to liquid metal flow and communication through the metal-eye 18. Once the metal level is at its maximum 45, the bay compartments 22, 23, 24 and 25, can easily be skimmed through the skimming doors 26, 27, 28 and 29.

The gas flowrate per impeller, Q (normal cubic metres/second), is estimated from the following equation:

$$Q = W \times A/N \qquad\qquad (1)$$

where   W is the metal flow rate, kg/s

A is the specific fluxing gas requirement, normal cubic metres/kg metal

N is the number of impellers

The specific fluxing gas requirement, A, is determined by experimentation or for start-up cases, the amount of gas can be estimated based on the amount of chlorine used for fluxing the alloy in the conventional chlorine practice. The amount of chlorine addition is less than 5% of the gas flowrate per impeller, depending on the type of alloy.

2073706

Once the total fluxing gas flowrate (inert gas and chlorine) has been determined using Equation (1), the impeller speed, N (revolution per second) can be estimated using the following equation:

5
$$N = \{KQT^a / (D^b H^c)\}^d \qquad (2)$$

where:

Q is the gas flowrate per impeller, normal cubic metres/second (Equation(1))

T is the equivalent cell diameter, metres

10 D is the impeller diameter, metres

H is the melt level in the cell, metres

K, a, b, c, and d are experimentally defined constants.

Equation (2) gives an approximate impeller speed

15 for good dispersion of the fluxing gas and good mixing of the metal bath under most operating conditions. Equation (2) shows that as more gas is introduced into the metal bath, it is necessary to increase the impeller speed to ensure good gas dispersion, and thus good metal refining.

20 It should be noted, however, that it is possible to operate at lower impeller speeds than predicted by Equation (2), depending on the desired degree of metal refining.

EXAMPLE.I:

25 18,410 kilograms of aluminium is to be refined in 54

minutes wh⬤ is equivalent to a refini⬤te of 5.73 kg/s (755 lbs/min.). The specific fluxing gas requirement is 0.0008 normal cubic metres/kg metal. The amount of chlorine addition is 2% of the fluxing gas flowrate. The system contains two impellers and is characterized by the following dimensional constants: H = 0.88 metres, D = 0.254 metres, T = 0.75 metres. From Equation (1), the fluxing gas flowrate is 0.0023 normal cubic metres/s (138 l/min) per impeller. From Equation (2), the required impeller speed is 4.84 rps (290 rpm). In practice, an impeller speed and fluxing gas flowrate of 5 rps (300 rpm) and 0.0027 normal cubic metres/s (160 l/min), respectively, were found to be more than adquate to reduce the hydrogen content of the metal from 0.27 ml/100g to below a target level of 0.15 ml/100g. The final level of hydrogen in the metal obtained under these operating conditions were 0.11 ml/100g.

EXAMPLE.II:

26,000 kilograms of alloy selected from 6000 series is to be refined in 42 minutes, which is equivalent to a refining rate of 10.4 kg/s (1375 lbs/min). The specific fluxing gas flowrate is 0.0006 normal cubic metres/kg metal. The amount of chlorine addition is 1% of the fluxing gas flowrate. The system contains two impellers and is characterized by the following operating constants: H = 0.93 metres, D = 0.254 metres, T = 0.75 metres. From

Equation (1), the fluxing gas flowrate is 0.0031 normal cubic metres/s (187 l/min) per impeller. From Equation (2), the required impeller speed is 5.5 rps (330 rpm). In practice, an impeller speed and fluxing gas flowrate of 5 rps (300 rpm) and 0.0023 normal cubic metres/s (140 l/min) were found to be more than adequate to reduce the hydrogen content of the metal from 0.24 ml/100g to below a target level of 0.15 ml/100g. The final level of hydrogen in the metal obtained under these operating conditions was 0.11 ml/100g.

CLAIMS

1.   A reaction vessel comprising:

a)   an inlet chamber which communicates with a
holding furnace and is equipped with means for heating the
molten metal flowing into the inlet chamber;

b)   at   least   one   reaction   chamber   which
communicates with the inlet chamber and has an opening in
its roof through which a rotary injection device may be
inserted; and

c)   a settling chamber which communicates with
said   reaction   chamber   and   contains   a   taphole   on   an
exterior wall of the vessel.

2.   A reaction vessel as defined in claim 1, which
is a bay within a holding furnace and is isolated from the
hearth of the holding furnace by means of a high thermal
conductive   wall   extending   alongside the   wall   of   the
furnace, said high thermal conductive wall having a sub-
surface metal eye opening communicating with said inlet
chamber.

3.   A reaction vessel as defined in claim 1, wherein
the reaction chamber consists of a first stage reaction
chamber which is connected to a second stage reaction
chamber through an underflow opening, each chamber having
a roof opening for the insertion of a rotary injection
device.

4.   A reaction vessel as defined in claim 3, wherein

2073706

said inlet chamber is separated from said first stage reaction chamber, said first stage reaction chamber from said second stage reaction chamber and said second stage reaction chamber from said settling chamber by high thermal conductive walls having said underflow openings at the bottom.

5.   A reaction vessel as defined in claim 1, wherein vertical baffles are incorporated on either side of the reaction chambers and located directly in front of the injection device to minimize splashing and vortexing of the liquid metal and thus excessive dross formation.

6.   A reaction vessel as defined in claim 1, wherein said rotary injection device comprises a rotary shaft having a central passage therein for feeding a fluxing gas mixture consisting of inert gas containing less than 5% chlorine, and an impeller with equally spaced blades and radial orifices located between the blades and connected to said central passage.

7.   A reaction vessel as defined in claim 6, wherein the radial orifices of said impeller are connected to a central windbox which is itself connected to said central passage.

8.   A reaction vessel as defined in claim 6, wherein the shaft of said injection device is driven by a motor drive assembly located above the roof of the bay.

9.   A process for removing solute hydrogen,

alkali/alkaline earth metals, and non-metallic inclusions, while minimizing dross formation, diminishing oxide patch occurence, during metal flow from a holding furnace to a casting table using a reaction vessel as defined in claim 1, said process comprising the steps of:

a)   shutting off the gas burner in the reaction vessel and introducing a rotary injection device into the reaction chamber of the reaction vessel;

b)   creating an inert atmosphere within the reaction vessel;

c)   introducing argon-chlorine fluxing gas mixture into the reaction chamber through said rotary injection device for a predetermined injection period;

d)   tapping out the refined molten metal from the taphole in the settling chamber continuously, while feeding untreated molten metal into the inlet chamber and continuing to inject fluxing gas mixture into the molten metal in the reaction chamber;

e)   collecting most of the non-metallic inclusions and halides in a dross layer above the liquid metal in the reaction chamber;

f)   collecting the remaining suspended halide droplets and the runaway dewetted non-metallic inclusions in the settling chamber of the reaction vessel;

g)   allowing the molten metal height to drop to a minimum level determined to be equal to the height of

2073706

the taphole in the settling chamber;

h) stopping the metal flow through the taphole, and transferring a new batch of molten metal into the reaction vessel thereby raising the metal level, and

5   i) removing the dross from the surface layer of liquid metal by skimming.

10. A process as defined in claim 9, wherein the inert atmosphere within the reaction vessel is maintainted higher than atmospheric pressure outside, thereby creating

10   a positive pressure and eliminating the possibility of hydrogen pick-up from the atmosphere.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

2073706

Fig. 5

Fig. 6

SECTION A-A

52

62

65

61   63

66

Fig. 7a

61

62

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Fig. 7b